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VVER FUEL CYCLE DEVELOPMENT AT SLOVAKIA

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ABSTRACT

Four VVER-440 units are now under exploatation at Bohunice-site in Slovakia. Fuel cycle development of Unit No3 and No4 (type 213) is discussed and compared with equilibrium cycles in this paper.

1. Equilibrium cycles

Gradual burnup growth can be described also by characteristic equilibrium fuel cycles. Three cycles with different amount of 4-year fuel and with effective cycle length about 290 full power days (FPD) are of interest for comparison with actual Bohunice cycles (Fig. 1÷12):

a) 3-year fuel cycle
- older, connected with VVER-440 reactor project
- odd and even loading patterns
- standard fuel
- no burned fuel assemblies (FA's) on the periphery
- no 4-year fuel

b) 3.5-year fuel cycle
- one loading pattern
- standard fuel
- 42 burned FA's on the core periphery
- 42 4-year FA's (6 of them in the core center)

- equilibrium cycle with the lowest radial leakage

c) 4-year fuel cycle
- one loading pattern
- advanced fuel
- 30 burned FA's on the core periphery
- 78 4-year FA's (all fresh fuel except control assemblies (CA's), 54 of them in the core center)

Three enrichments - 3.6, 2.4, 1.6 - are used in all cycles (Bohunice included). CA's are used 3 years maximally in the core. Growing of 4-year FA's number is compensated by increasing initial enrichment. Gradual falling of power peaking with growing amount of 4-year fuel is caused mainly by improvement of in-core optimisation methods and by periphery structure (Fig.9).

Some parameters of the oldest 3-year cycle are not in agreement with advanced safety requests (low CA group No6 efficiency, high CA shot reactivity release,...). All safety important parameters of 3.5 and 4-year cycles are in safety acceptable ranges (examples - see Fig.9÷12).

2. Fuel cycle of Bohunice Unit 3 and 4

Development of VVER-440 fuel cycle in Slovakia is characterised by gradual growing of discharged burnup (Fig.5) i.e. by moving from 3-year (design) to the four-year cycle (Fig.6). This process is described by parameters of 8 cycles of Nuclear Power Plant Bohunice Unit 3 and 4 in comparison with three equilibrium cycles (Fig.1÷12)

All cycle parameters are influenced mainly by desired cycle lengths that are in agreement with grid demands and

are very short for last cycles. Actual values vary in the range of 245÷330 FPD. First successful attempts with 4-year fuel were made at cycles 4 and 6. Number of 4-year assemblies increases gradually starting from cycle 9 and 7 of Unit 3 and 4. Target value 78 four-year FA is reached at cycles 11 and 10. Maximal discharged burnup of 4-year fuel batch 38.9 MWd/kgU was reached at Unit 4. Burnup growth is connected with decreasing of temperature reactivity coefficients (Fig.12).

There is no negative influence on safety related parameters and failure rate caused by growing of the core burnup. Values of all mentioned parameters are found in safety acceptable ranges.

3. Economy

Economical effect of 4-year fuel is as follows:

Fuel cycle	Specific fuel cost [%]
3-year	112
3.5-year	100
4-year	95.1
Unit 3 cycles 4÷8 Unit 4 cycles 3÷7 3-year cycle	108.9
Unit 3 cycles 9÷11 Unit 4 cycles 8÷10 moving to 4-year cycle	94.9

First 5 cycles of Units 3 and 4 are without or only with small amount of 4-year fuel. Last 3 analysed cycles of it are characterised by rapid growth of 4-year fuel to target value 78 4-year FA's. Specific fuel cost of first 5 cycles is relatively close to 3-year cycle. Difference is caused by small number of 4-year fuel an by stretch-outs. Cost of last 3 cycles is close to 4-year cycle. Difference

is caused by stretch-outs. Economy estimate connected with establishing of 4-year cycle is higher than 10% of specific fuel cost.

4. Conclusion

Movement from 3 to 4-year fuel cycle at Slovak reactors VVER-440 causes no safety problems and brings significant fuel economy.

Fig.1 ENRICHMENT

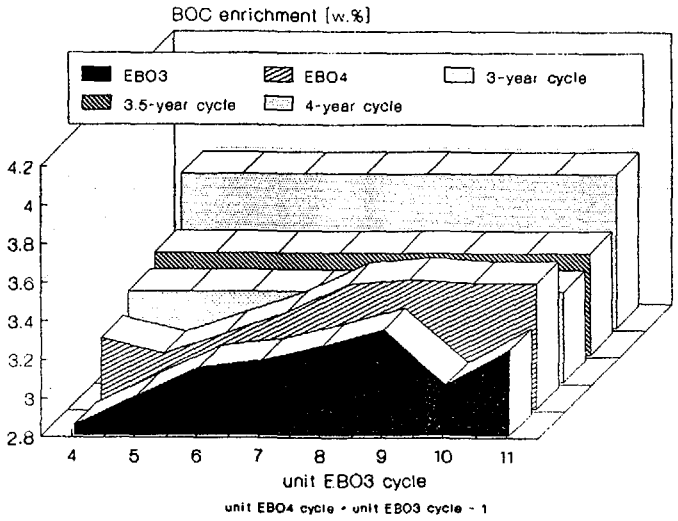


Fig.2 BOC BURNUP

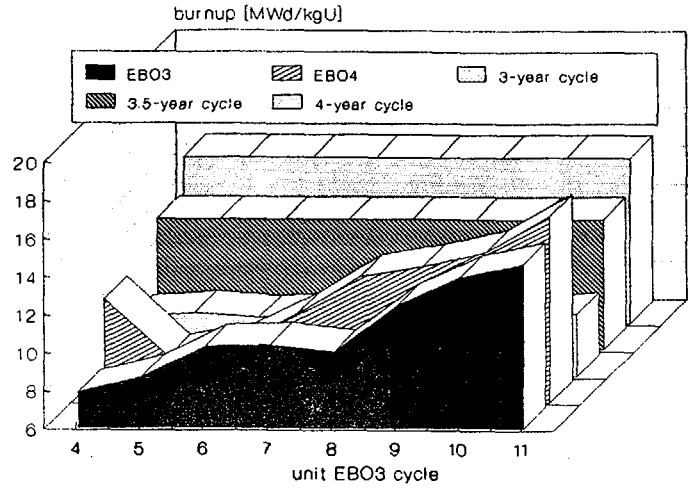


Fig.3 BOC PERIPHERY BURNUP

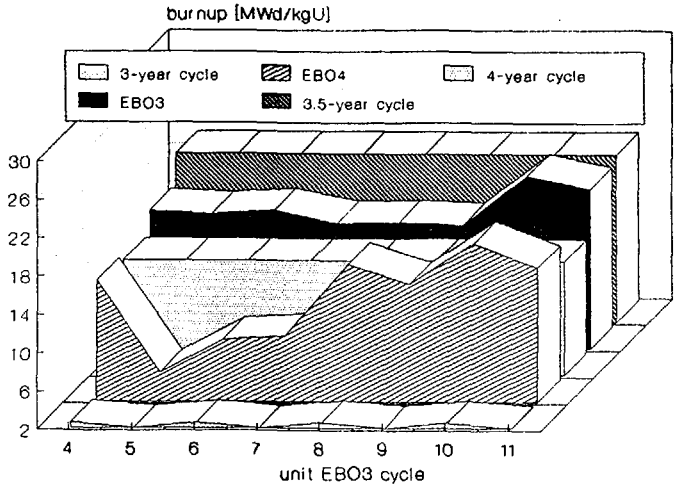


Fig.4 CYCLE LENGTH

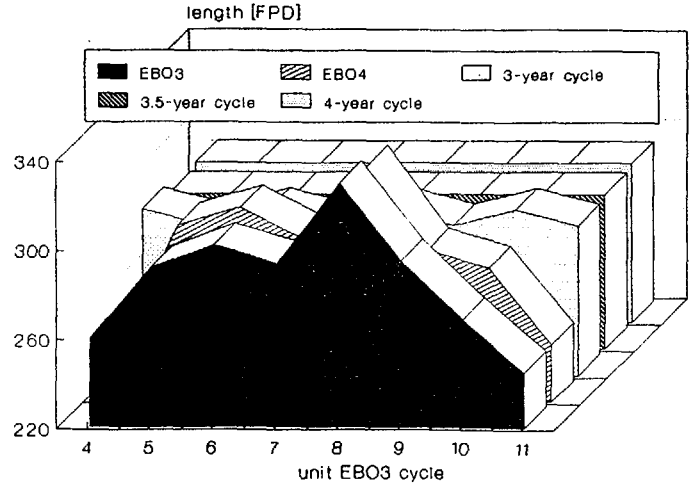


Fig.5 DISCHARGED BURNUP

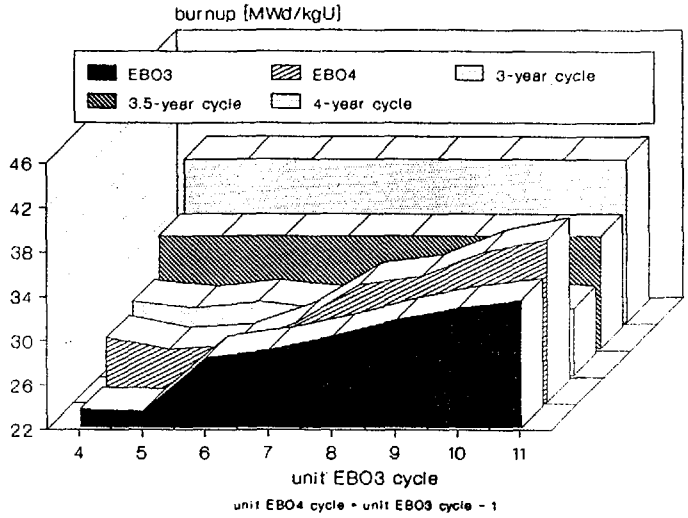


Fig.6 4-YEAR FUEL

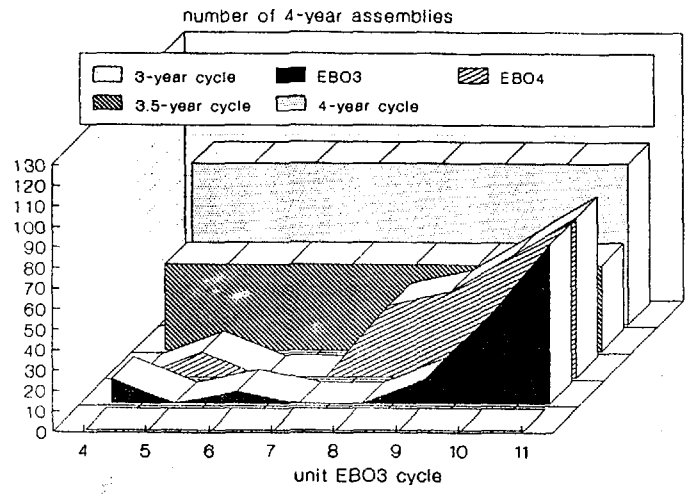


Fig.7 4-YEAR FUEL DISCHARGED BURNUP

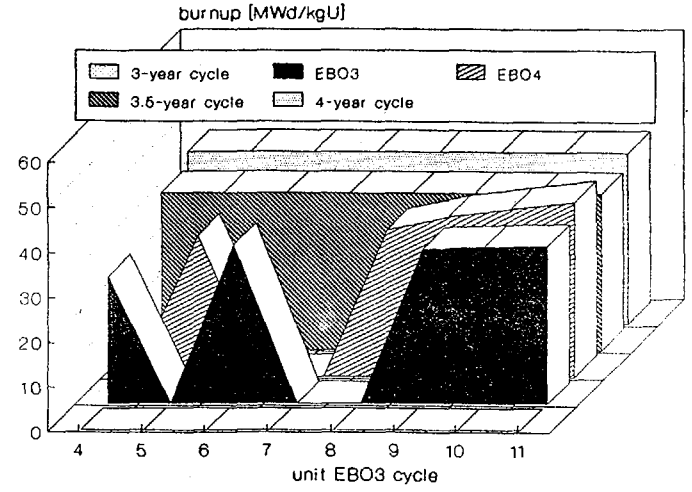


Fig.8 4-YEAR FUEL - MAX. FA BURNUP

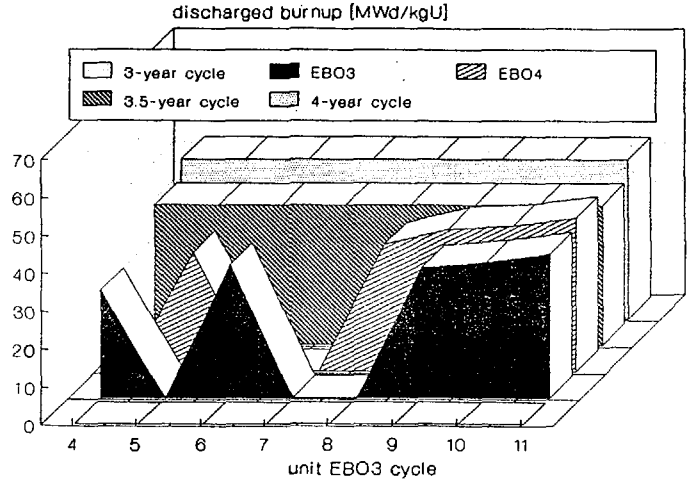


Fig.9 ASSEMBLY POWER PEAKING FACTOR

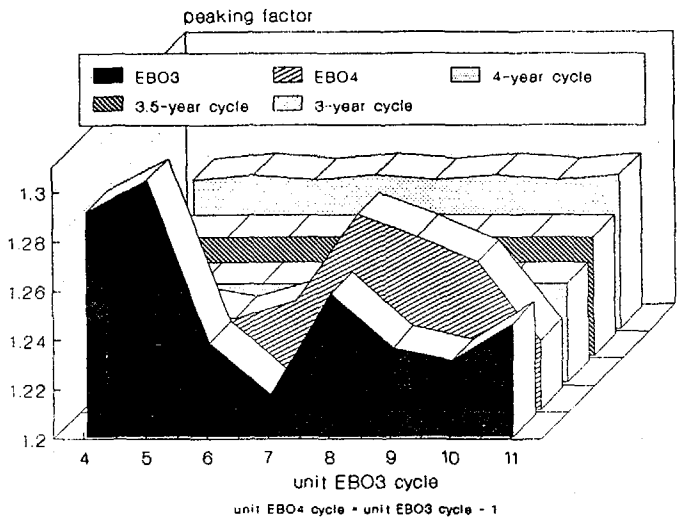


Fig.10 CA GROUP No6 EFFICIENCY
BOC, nominal parameters

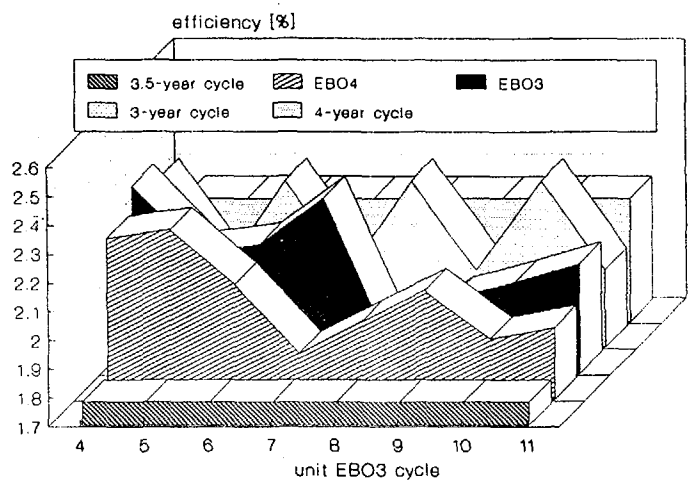
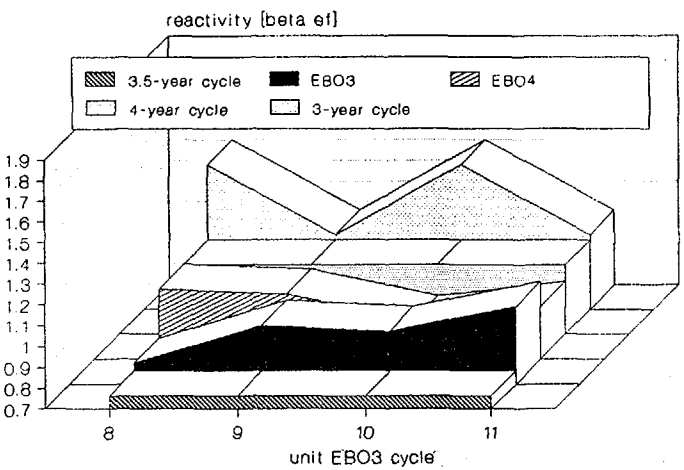


Fig.11 CA SHOT REACTIVITY RELEASE
EOB, zero power, Tm = 285 C



the most efficient group No6 CA shot
initial position 50 cm

Fig.12 MODERATOR REACTIVITY COEFFICIEN
BOC, Tm = 200 C, H6 = 175